

**Office of Oversight
Environment, Safety and Health**

*Type A Accident Investigation
of the December 8, 1999*

**Multiple Injury Accident
Resulting from the
Sodium-Potassium Explosion
in Building 9201-5
at the Y-12 Plant**

February 2000



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OVERSIGHT

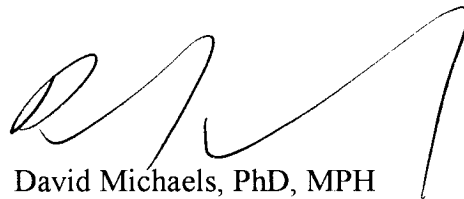
PROLOGUE

The December 8, 1999 chemical explosion at the Y-12 Plant that injured 11 workers, three of whom required hospitalization, could have been prevented. The explosion resulted from the failure of the many barriers that we count on to prevent or mitigate such accidents, and in particular, the failure of the site to implement Integrated Safety Management.

This Type A accident investigation shows that there were failures associated with Integrated Safety Management within the DOE Oak Ridge Operations Office and at every level of the Lockheed Martin Energy Systems management chain. These failures caused numerous missed opportunities to prevent the inadvertent spill and spraying of NaK and the consequent explosion. I am especially concerned with the lack of understanding and appreciation for the chemical hazard involved and the failure to pursue additional information or expertise in the face of unusual or unexpected conditions.

Integrated Safety Management is not a paper exercise; it is not a philosophy. ISM must be a way of doing business every day, for both management and workers. This accident highlights the importance of an integrated and standards-based approach to safety that stresses implementation of the five core functions of integrated safety management by all levels of an organization.

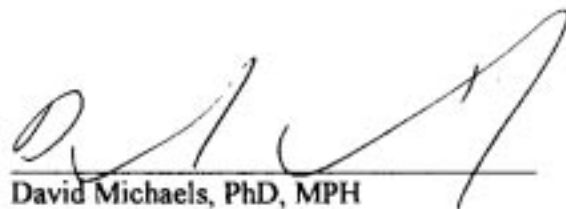
Significant and prompt senior DOE and Lockheed Martin management attention is needed to better protect workers by improving the way ISM and management systems are implemented. Lockheed Martin must take a comprehensive look at how it implements existing requirements so that the integrated approach to safety management is effective. Lockheed Martin must examine the clarity of roles, responsibilities, authority and accountability for implementing ISM. DOE-Oak Ridge, including the Y-12 Site Office, needs to strengthen its management oversight and field presence to provide feedback on the adequacy of ISM implementation.

A handwritten signature in black ink, appearing to read 'DM', with a long horizontal stroke extending to the right.

David Michaels, PhD, MPH
Assistant Secretary
Environment, Safety and Health

On December 9, 1999, I established a Type A Accident Investigation Board to investigate the December 8, 1999, multiple injury accident resulting from the explosion involving a sodium-potassium alloy at Building 9201-5 at the Y-12 Plant, in Oak Ridge, Tennessee. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations*.

I accept the findings of the Board and authorize the release of this report for general distribution.



David Michaels, PhD, MPH
Assistant Secretary
Office of Environment, Safety and Health

2/24/2000
Date

This report is an independent product of the Type A Accident Investigation Board appointed by Dr. David Michaels, Assistant Secretary for Environment, Safety and Health (EH-1).

The Board was appointed to perform a Type A Investigation of this accident and to prepare an investigation report in accordance with DOE 225.1A, *Accident Investigations*.

The discussion of facts, as determined by the Board, and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

Executive Summary

Accident

On December 8, 1999, at 9:35 a.m., a chemical explosion occurred within the skull caster furnace section of the Building 9201-5 at the Y-12 Plant in Oak Ridge, Tennessee. The explosion injured 11 workers, three of whom required hospitalization. One worker had third-degree burns on 17 percent of his body and was flown to the Erlanger Burn Center in Chattanooga, Tennessee. The worker was initially considered to be in critical condition and received a number of skin grafts before leaving the hospital on December 21, 1999.

On Thursday, December 9, 1999, the Department of Energy (DOE) Assistant Secretary for Environment, Safety and Health chartered a Type A investigation board to investigate the accident. The Board arrived on site on Friday, December 10, and completed the investigation in January 2000.

Background

On December 1, 1999, Depleted Uranium Operations (DUO) workers in Building 9201-5 were changing out the crucible in the skull caster furnace. This crucible is cooled by a sodium-potassium liquid metal alloy (NaK). The crucible was last changed out in 1993, and the workers were using a new procedure for the activity. When workers removed a flexible argon purge hose from the crucible, several gallons of NaK sprayed out through an open isolation valve into the furnace.

Over the next several days, the workers monitored conditions in Building 9201-5 and intermittently purged the furnace with argon in an attempt to minimize further oxidation. Facility management developed a recovery plan outlining the process for cleaning up the NaK spill. On Friday, December 3, the workers observed unusual and unexpected conditions in the furnace, including a yellow color and abnormal configuration of the material. Mineral oil was sprayed on the deposits to minimize oxidation.

On December 8, the explosion occurred while the workers were attempting to clean up the NaK

using a vacuum probe and metal rod, having sprayed additional mineral oil. The direct cause of the explosion was the impact of a metal tool on a shock-sensitive mixture of potassium superoxide (KO_2) and mineral oil.

Results and Analysis

Some aspects of the emergency response to this accident were effective. For example, the workers promptly assisted the most severely injured workers to the safety showers. In addition, the fire department and radiation control personnel responded promptly and effectively to transport the injured personnel and prevent the spread of contamination. However, the accident highlighted deficiencies in numerous aspects of safety management at the Y-12 Plant.

The December 1 NaK spill resulted from numerous deficiencies in the new procedure for crucible changeout. During this work activity, the workers made pen and ink changes without stopping to obtain proper review and approval of the changes. A key step requiring opening of the dump valve to drain the crucible NaK piping had been inadvertently deleted from the procedure, resulting in a failure to open the valve and trapping the remaining NaK under argon pressure. When workers observed an unexpected NaK level in the sump, they did not stop to analyze the system configuration or seek assistance before repeating parts of the procedure. A worker climbed into the furnace to disconnect the argon purge hose. When the hose was disconnected, the trapped NaK sprayed out under pressure into the furnace through an open isolation valve that was also incorrectly aligned because of procedural deficiencies.

In addition to other deficiencies, the changeout procedure was designated Category 3, which does not require verbatim step-by-step compliance. However, the hazards of the work merited a Category 1 procedure, which would have required steps to be followed in sequence, signoffs for key steps, and management review of any changes prior to implementation.

After the spill, facility management stopped work to develop a recovery plan for cleaning it up. The plan was developed in one week using a team approach, including personnel from safety engineering and the industrial safety/hygiene organization. However, the personnel who developed the recovery plan did not adequately understand the hazards associated with superoxide explosions and the use of mineral oil. Further, the recovery plan did not conform to authorized Y-12 Plant mechanisms for controlling hazardous activities. The process did not include a hazard screen or job hazard analysis, and the plan was not subjected to any management or technical review or approval beyond the core group that developed it. The plan failed to address the necessary personal protective equipment (PPE) for the workers engaged in the hazardous NaK recovery; such equipment could have mitigated or prevented the injuries that were incurred.

The crucible changeout procedure and recovery plan did not identify or control the explosion hazard associated with potassium superoxide in the presence of organic materials, such as mineral oil. The explosion hazard is clearly identified in the NaK Material Safety Data Sheets required by the Occupational Safety and Health Administration and in many other documents and publications available on site, including the safety analysis for another Y-12 Plant facility. The recovery plan directed workers to spray the NaK spill with mineral oil and to mechanically break up NaK that could not be vacuumed out. These very actions and conditions caused the explosion and worker injuries.

In both crucible changeout and NaK spill recovery, facility management indicated to the Board that they were attempting to implement the DOE integrated safety management (ISM) policy. The development of a detailed crucible changeout procedure and the use of a multi-disciplined planning group are positive indications of this intent. In both activities, however, the actual implementation of ISM was significantly deficient, indicating a lack of understanding of the policy, a failure to adhere to established procedures, and a continuing reliance on informal, expert-based approaches to work and hazard control. Senior facility management was not adequately involved in the development, categorization, review, validation, or modification of procedures and plans. In addition, although the DUO organization has made progress in implementing ISM, it has not effectively utilized the lessons learned from other events and accidents at Y-12 and throughout the DOE complex, indicating continuing weaknesses in the understanding,

acceptance, and implementation of improved safety management programs and processes.

Management at all levels and safety professionals, such as industrial hygienists, did not maintain an adequate level of knowledge on the well-documented hazards associated with NaK. Because previous NaK spills and events had not caused serious injuries, management and work planners apparently developed a level of confidence in their familiarity with NaK and did not seek outside expertise. Inadequate understanding of the hazard, as well as failure to follow the contractor's ISM work control processes, resulted in a hazard analysis and hazard controls that were ineffective in preventing or mitigating the accident.

This accident highlighted weaknesses in programs and processes essential to safety, such as procedure quality, use, and change control; system configuration control; unreviewed safety question determinations; and training. These weaknesses persist, in part, because of a lack of management involvement in safety and weaknesses in the contractor's independent quality assurance function, line management self-assessment programs, and DOE oversight. Further, the December 1 spill was not reported to contractor senior management, safety engineering, the DOE Facility Representative, or the DOE Occurrence Reporting and Processing System as required.

At the activity level, workers involved in crucible changeout and NaK spill cleanup demonstrated a lack of understanding of ISM requirements and a continuing heavy reliance on informal work controls and skill of the craft. When procedures did not work as written, they were changed in process without management review or approval. When workers encountered unusual or unexpected conditions, they continued their activities, including spraying oil, without stopping to obtain appropriate management or technical assistance. ISM would require, as a minimum, revisiting the hazard analysis and reconsidering the hazard controls when, for instance, workers encountered a low NaK sump level or observed unusual conditions and suspected superoxides in the furnace. Given the long history of uneventful use of mineral oil and the level of confidence in its use, it is not clear what would have prompted the DUO workers to stop work and seek guidance. The willingness to stop work and obtain management and technical assistance when procedures or instructions do not work, or when unusual or unexpected conditions arise, is fundamental to effective safety management. Failures in the safety management system contributed to the accident and indicate that Y-12 has not yet developed a standards-based safety culture.

The Board determined that the contractor, Lockheed Martin Energy Systems (LMES), has not effectively incorporated the lessons learned from previous events and accidents, thereby missing a number of opportunities to prevent this accident. In 1992, an NaK release at this same facility prompted corrective actions that involved specific PPE requirements for workers who could come in contact with NaK—requirements not incorporated in the NaK spill cleanup plan. In 1994, LMES generated a lessons-learned document based on a sodium explosion in France that killed one worker and injured four. The facility's response to that document was inadequate, and neither workers nor management questioned its adequacy. In 1997, when an NaK drum and a small reactor containing NaK were discovered in another Y-12 facility, management recognized that the facility safety analysis report did not address these hazards. As a result, the facility filed an unusual occurrence report and performed a hazard screening evaluation that clearly identified the explosion hazard and the chemical reaction that would cause an accident like the one that later occurred in Building 9201-5. However, this hazard information was not effectively communicated to or utilized by workers or planners in Building 9201-5.

In the last five years, Lockheed Martin has experienced six serious accidents resulting in Type A investigations at the Oak Ridge and Idaho National Engineering and Environmental Laboratory facilities it manages for DOE. These accidents included three fatalities and several serious injuries. In each of the two most recent accidents, ten or more workers were exposed to hazardous materials. Similar deficiencies led to these accidents: inadequate procedures or

procedure use; overreliance on skill of the craft; informal or inadequate hazard identification, analysis, or control, particularly for work that was considered routine; lack of management involvement and supervision; and inadequate training or competence. Until these systemic deficiencies are corrected, undesired events and accidents are likely to continue, and LMES will not be able to implement ISM fully and effectively.

Conclusions

The Board concludes that this accident and the resulting injuries were preventable. The line managers and work planners responsible for the workers' safety did not understand the imminent hazard of the interaction of the materials and therefore did not provide appropriate hazard controls or worker protection. The deficient level of control resulted from inadequate hazard analysis and unreviewed safety question screening, and from overreliance on past practices and skill of the craft.

LMES needs to expedite full and effective implementation of the DOE ISM policy at DUO and in its non-nuclear facilities. To do so, LMES will need to significantly strengthen the supporting infrastructure and processes, including procedure quality and adherence; the authorization basis and unreviewed safety question determination processes; hazard identification and analysis; quality assurance; and training. In addition, LMES and DOE need to increase their presence in the field to promote and provide training in the tenets of ISM and to provide feedback on progress and lessons learned.

Table ES-1. Root Causes and Summary of Judgments of Need*

Judgments of Need	Root Causes
#1: Strengthen the training and competence for workers and for managers, engineers, and safety and health professionals responsible for worker safety.	LMES failed to establish, seek, or maintain an adequate level of knowledge and competence on the hazards associated with NaK, including the formation of superoxide, the incompatibility of superoxide and organics, and the explosive sensitivity of the mixture to impact or shock.
#2: Strengthen the implementation of the ISM core functions and existing LMES processes to assure that all potentially hazardous work and activities are subjected to effective, formal, and documented hazard analysis.	LMES's implementation of the hazard analysis and control processes failed to identify, prevent, or mitigate the explosive interaction of potassium superoxide, mineral oil, and impact. The NaK Material Safety Data Sheet was not used.
#3: Strengthen the identification and implementation of engineering, administrative, and worker protection controls for potentially hazardous work and activities.	LMES management systems and processes did not assure adequate procedures or controls to prevent the loss of system configuration control resulting in an NaK spill or to preclude the addition of mineral oil and impact in the presence of potassium superoxide during NaK spill recovery.
#4: Strengthen the implementation of the ISM feedback process through improved sharing of technical expertise and information and through use and appropriate application of lessons learned from events, accidents, and near misses.	LMES management failed to effectively communicate or utilize information from the hazard screening evaluation, lessons learned, previous events and accidents, studies, analyses, and publications in planning and controlling this work and the associated hazards to worker health and safety. Knowledge of this hazard and expertise to address it were readily available at the Oak Ridge Reservation and other DOE sites.
#5: Expedite the understanding, acceptance, and implementation of the ISM core functions through improved use of and adherence to work and hazard controls, including procedures.	OR, YSO, and LMES have not established or assured a safety culture that implements an ISM process in which workers are consistently held accountable for adherence to procedures and hazard controls and are willing to stop work and seek management and technical assistance when procedures do not work or abnormal conditions are encountered.
#6: Improve the identification, availability, and use of appropriate personal protective equipment to protect workers against work-related hazards. (NOTE: This provision has been a factor in the last three Oak Ridge Type A accident investigations.)	LMES management systems and processes were not effective in assuring the provisions for and use of appropriate personal protective equipment for working with a pyrophoric liquid metal and protecting against thermal and caustic chemical burns and the inhalation of toxic and radioactive smoke.

* More detailed judgments of need are delineated in Section 4 of this report.